Final Report of Scientific Results

Fixed Phase Variability in RS Canum Venaticorum Stars

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Lawrence W. Ramsey
Principle Investigator

Introduction:

This research program utilized the International Ultraviolet Explorer satellite to obtain UV spectroscopy of RS Canum Venaticorm (RS CVn) stars. In particular we studied the behavior of activity sensitive spectral features in RS CVn systems. The goals of this investigation were to obtain wide UV spectra at *fixed phases* of the target stars in order to determine if the stochastic variations at one location were similar to the variations seen over the entire longitude range in the star seen by others.

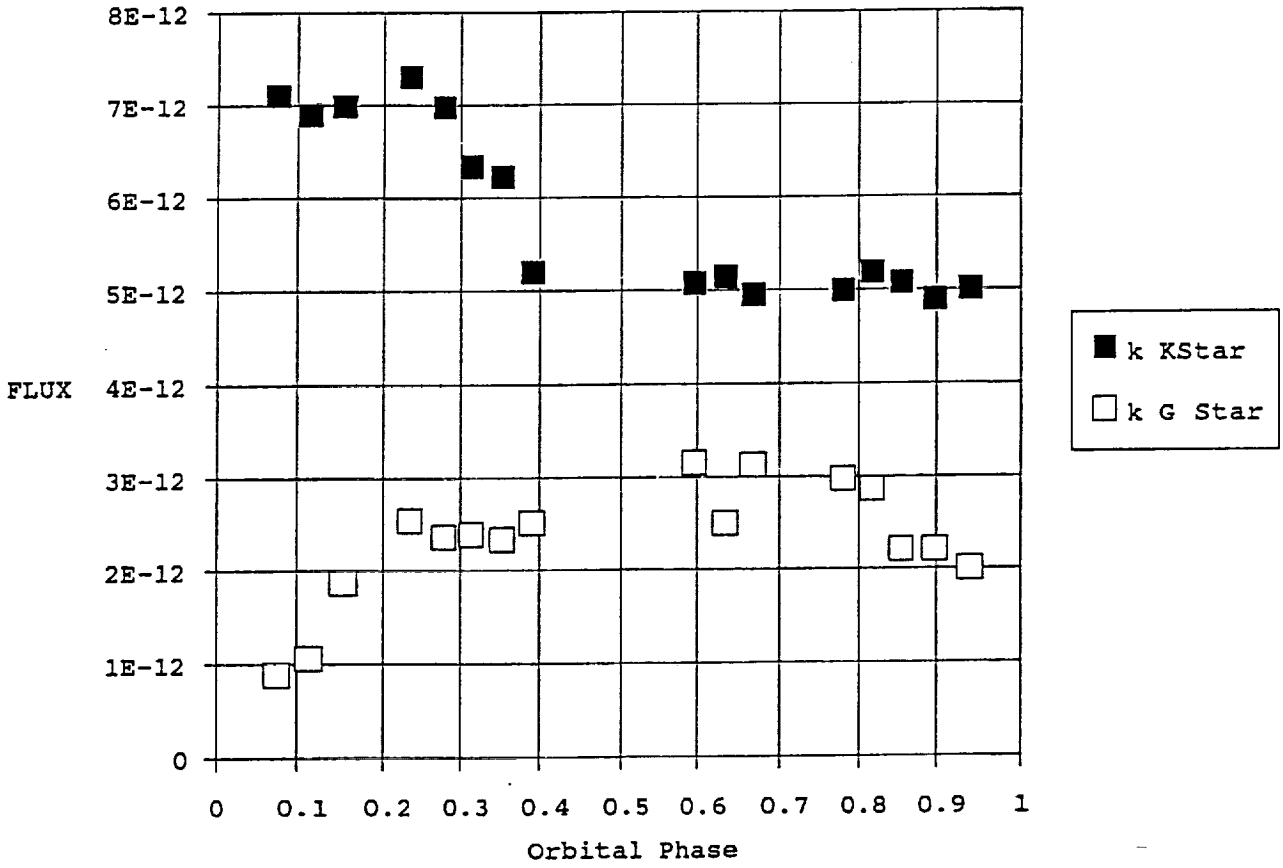

Fig 1. Variation of the MgII line in AR Lac with orbital phase.

RS CVn stars are late type binary systems which exhibit strong Ca II K line emission as well as a photometric distortions wave. Hall suggested a distinction between the short period ($P < 1$ day), regular, and long period ($P > 2$ weeks) RS CVn binaries. Linsky divides the regular and long period (LP) systems at about 20 days as systems with periods longer than 20 days will not have had time to have their orbital and rotation periods synchronized.

One or both components in these systems are considered to have active regions on their surface akin to those on the sun. The current paradigm for understanding these objects is an extension of what we know about magnetic activity on the sun. The photometric distortion wave is modeled by cool starspots and variable Ca II H & K as well as Hα emission in the visible have been interpreted as arising in associated plage-like regions as are the variation in chromospheric and transition region lines in the UV. The X-ray emission has been modeled in terms of solar

coronal loop structures and radio emission has been used in attempts to detail coronal structure. Interpretation of flare-like outbursts in these systems has also relied on our solar experience.

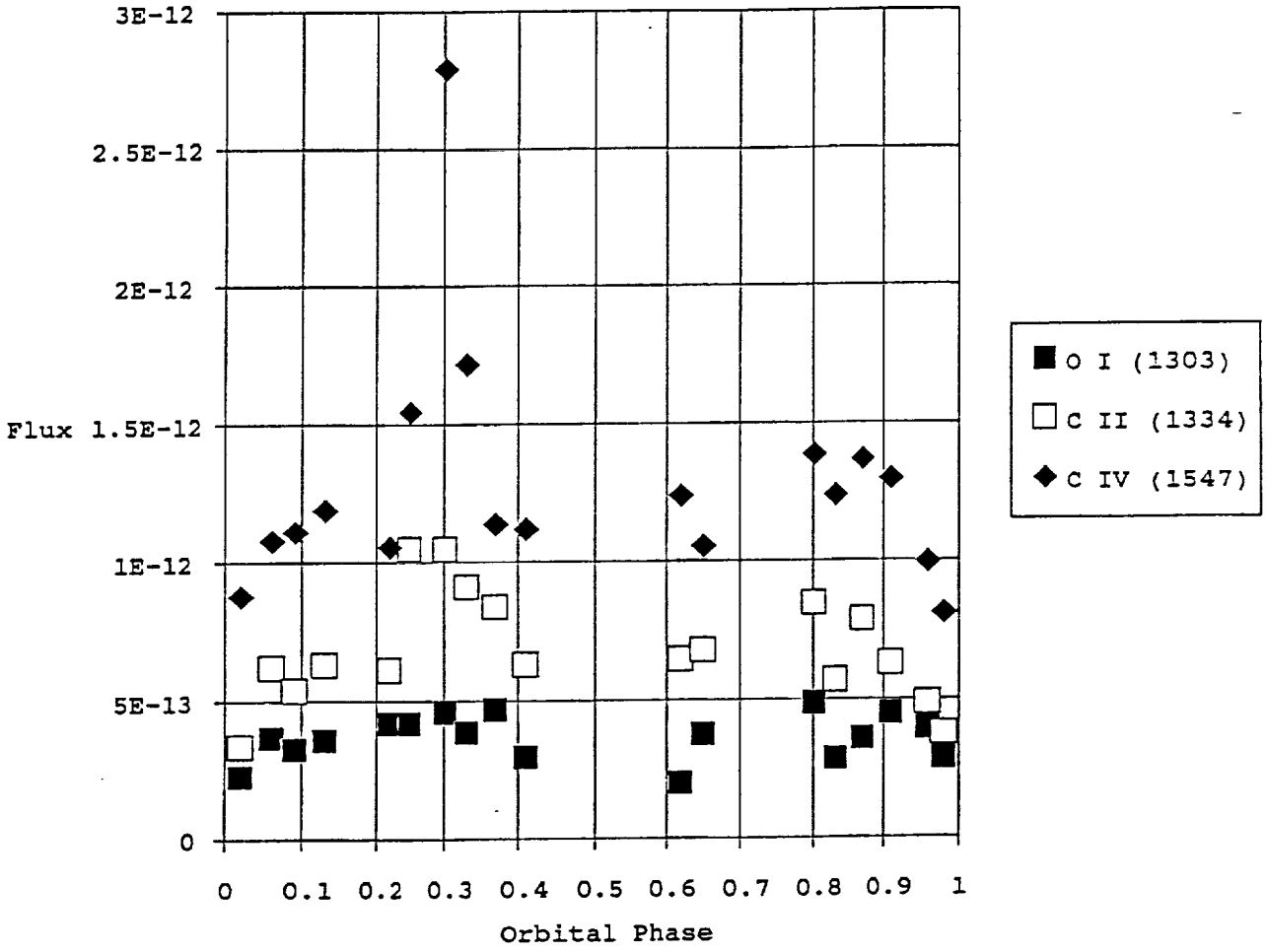

Fig 2 Variation of the OI, CII and CIV lines with orbital phase in AR Lac.

The paradigm for studying these stars is rotational modulation. Here one looks at a target at different rotational phases with the objective of utilizing the variability one sees in activity sensitive features to probe the surface structure of the star. Figure 1 illustrates a classic rotational modulation study undertaken by Neff and his collaborators for AR Lac in the Mg II emission line which arises in the chromosphere. Figure 2 illustrates the rotational modulation observed in the transition region lines from Carbon and Oxygen

Results

The observations were carried out with IUE in the summer of 1990 for three RS Cvn systems. These were AR Lac, SZ Psc and Z Her. These systems all have nearly integral day periods making fixed phase observations easily obtained with the IUE scheduling criteria. During the month long observing run, the phases drifted slightly. However in all cases the visible hemisphere of the stars did not change by more than 10%. The results of this run are compared with the phase monitoring data on AR Lac obtained by Neff and his collaborators illustrated in Figures 1 & 2 above. The *fixed phase* results for AR Lac is given in Figures 3 and 4. Figure 3 shows the

fluxes for the Mg II lines taken over a period of 22 days. Figure 4 shows similar data for a variety of Transition region lines taken over a period of 30 days variety of emission lines in the UV region of AR Lac over the month long observing run. Inspection of our data in Figures 3 and 4 and

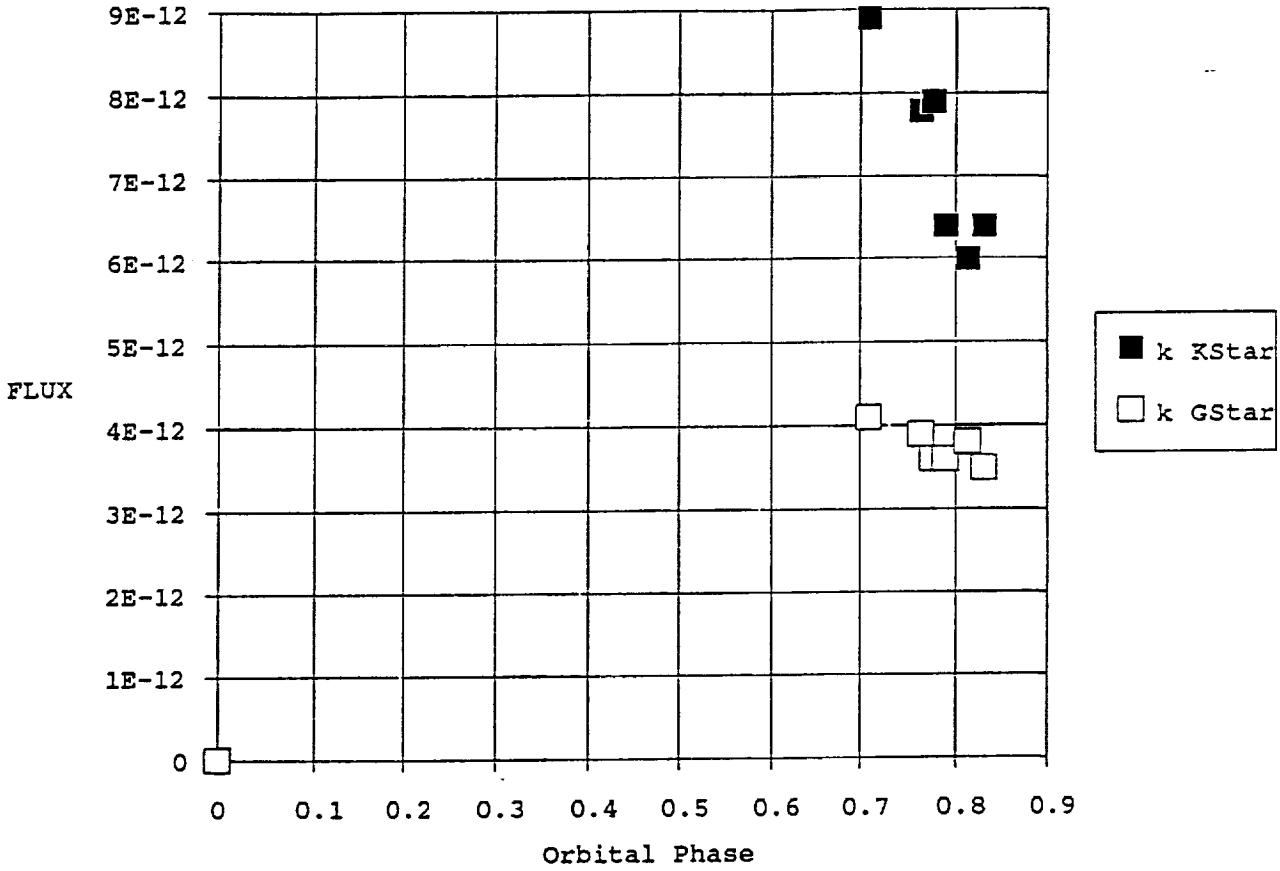

Fig 3. Fixed phase observation of AR Lac for MgII lines.

comparison with similar data in Figures 1 & 2 brings to light some interesting results. In Neff et al's data for AR Lac in 1985, both the G star and the K star show variation with the G star varying by nearly a factor of three and the K star by about 40 %. Our data in 1990 show the G star nearly constant at fixed phase but the K star fluctuating by nearly 50% at that same phase. The basic question this brings to mind is if the phase related activity is merely stochastic activity observed at different phases or truly indicative of a longitudinal dependence of the activity? Results for SZ Psc shown in Figure 5 only reinforces the point.

Conclusions

The major conclusion of this study is that rotational modulation is a shaky tool at best. It should only be employed when several rotations for the same star can be observed over a short period of time so that stochastic variations can be separated from those changes in line strength due to true longitudinal variation of surface activity. To do this properly will require the allocation of rather large amounts of telescope time to study individual objects.

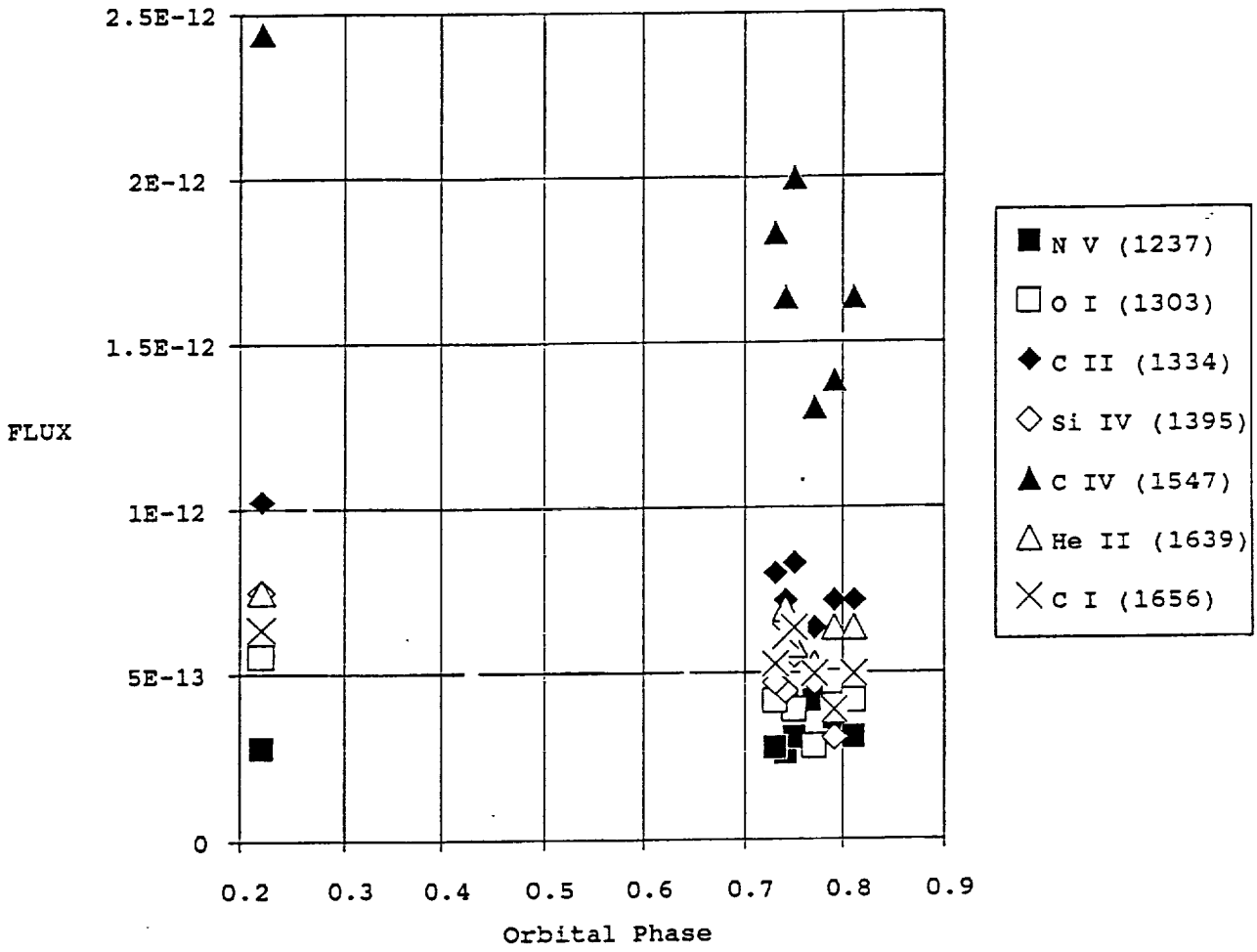

Fig 4. Fixed phase observation of AR Lac for transition region lines.

Another conclusion is that activity is highly variable on a daily and certainly weekly time scales. This can be seen from Figure 5. In this figure the same AR Lac data used in Figure 4 is plotted as a function of time instead of orbital phase. It is clear that all the lines are significantly variable. The CIV lines leads this lot by dancing around by nearly a factor of two.

As Figure 4 demonstrates that this is not rotational modulation it must be ascribed to the variation in the flux at one location on the star. This could be due to micro-flaring or to the evolution of flux tubes emitting regions at that longitude. In any case the time scale seems to be on the order of a day or two. This would imply that not only do we need to sample several rotations to understand the distribution of activity on these stars, but we also have to densely sample in time to understand the time scale for the changes at any given longitude. This type of dense sample; repetitive observation of single objects is not commonplace in spectroscopic observations. To properly execute it will place strains on space observatories.

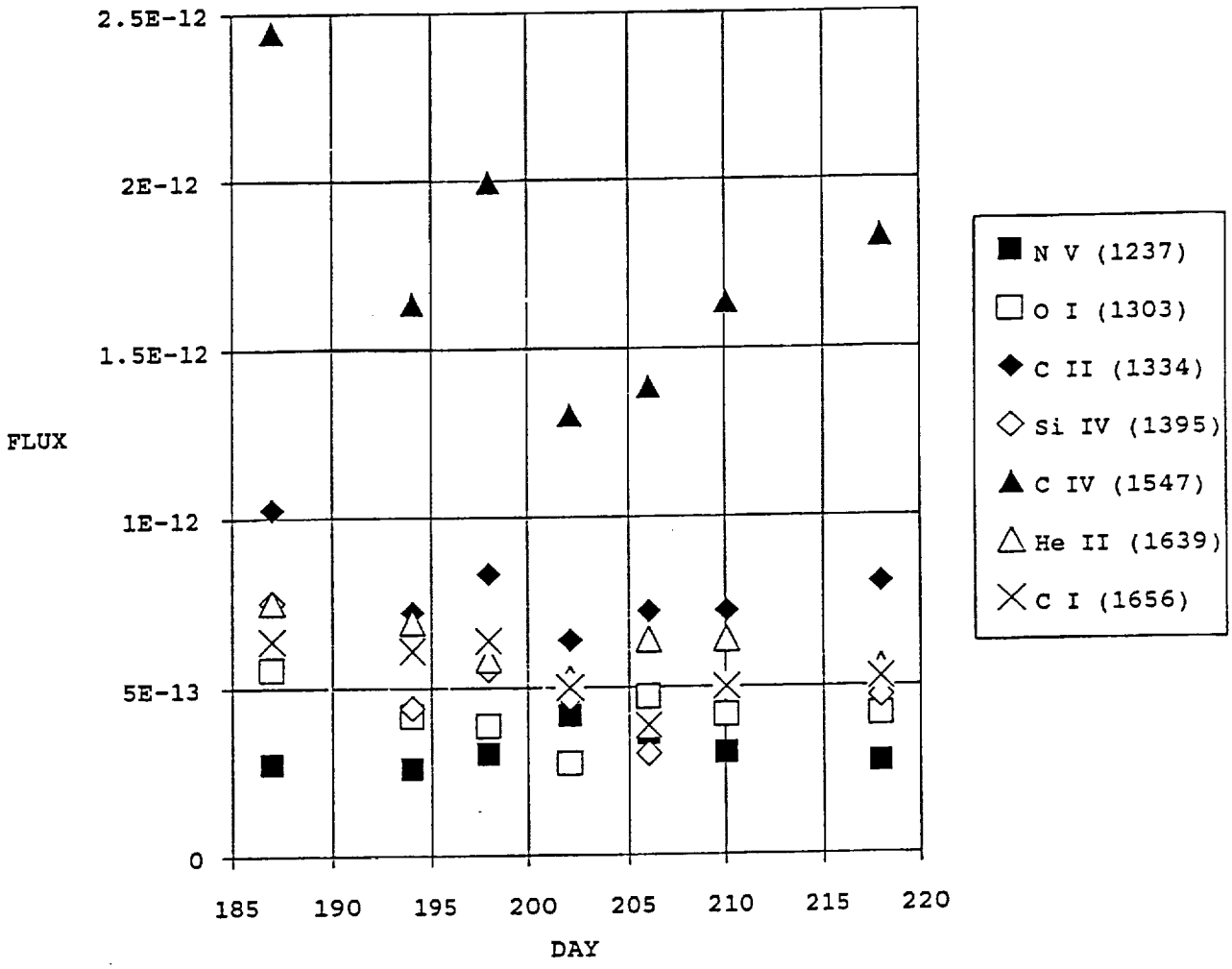

Fig 5 Time series observations of AR Lac for transition region lines.

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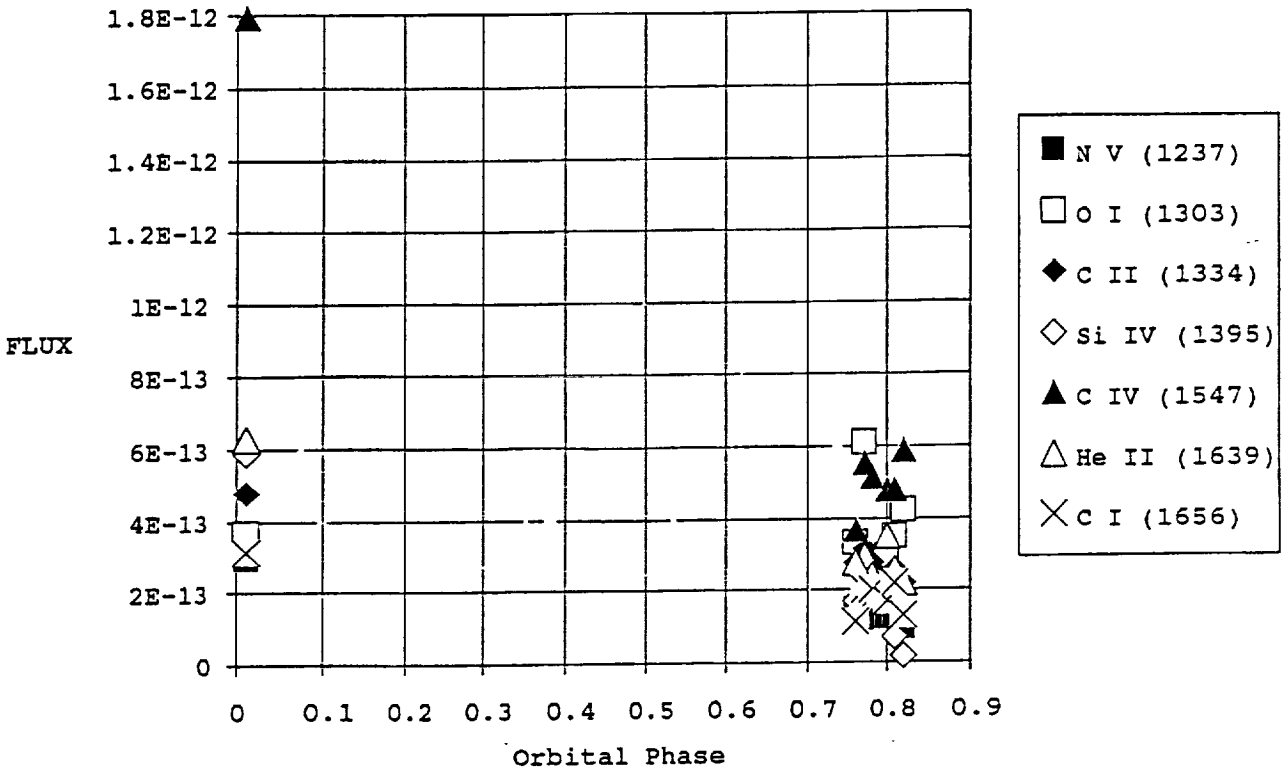

Fig 6. Fixed phase observation of SZ Psc for transition region lines.